National Aeronautics
and
Space Administration

ExAO high contrast experiments at Palomar

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Project Objective

Ground-based experimental precursors to nextgen high-contrast ground/space-based instruments

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Palomar Well-Corrected Subaperture

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ExAO = high/stable Strehl Ratio

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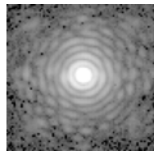
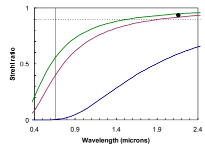
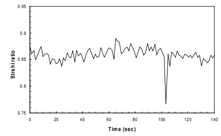
Coronagraphy | *Transit spectroscopy* | *Visible AO, speckle nulling*

Recent Results



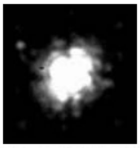


- Best Strehl ratio ~ 0.92-0.94
- WFE ~ 85 -100 nm rms
- *Strehl stability: 1 % rms*

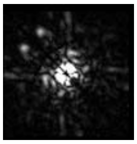


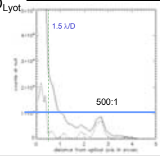
Four-Quadrant Phase-Mask Coronagraph

- The Brown Dwarf pair HD130948 at K_s
- Stellar rejection ~ 35:1
- ΔK_s = 6.9 ± 0.5
- separation = 2.61 ± 0.08"



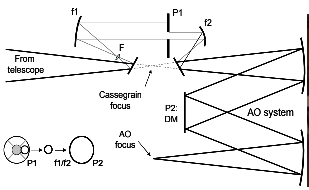
- At ~ 7.5 λ/D_{Lyot}
- Could see it to 1.5 λ/D_{Lyot}

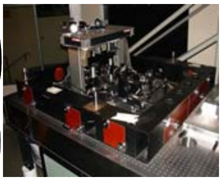




Project Description

Well-Corrected off-axis subaperture relay optics



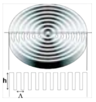


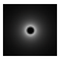
ExAO on-sky coronagraph testbed

- Off-axis unobscured pupil, high and stable Strehl = good working conditions for efficient coronagraphs
- Test coronagraphs in realistic conditions:
  - FQPM ;
  - Band-limited masks (J. Crepp, J. Carson, K. Wallace & J. Ge).
- Perform high-contrast imaging and Science:
  - companion around binary imaging,
  - close binaries,
  - brown dwarfs,
  - disks around bright stars.

Developments of new coronagraphs

- Optical Vectorial Vortex Coronagraph (OVVC)
  Annular Groove Phase Mask = OVVC2
  + small Inner Working Angle
  + high throughput
  + no quadrant transitions
  + achromatic





- Prototypes under manufacturing:
  - Silicon etching: MicroDevices Lab
  - Fused Silica deep etching: MEMS Optical
  - Hybrid Liquid Crystal Polymers: JDSU Uniphase

Future: Exoplanet transit spectroscopy

- High and stable Strehl enables high-precision photometric spectroscopy of transists.
- Goal: determine dayside temperature and atmospheric conditions.
- Primary target: HD189733b
- First run promising but,
  - need to improve the post-AO pointing stability ;
  - need a new H/K low resolution, high efficiency grism for PHARO.

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

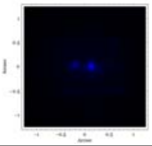
Image of HD189733 in the PHARO slit

Other Experiments with the WCS

Visible/Blue AO

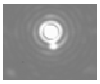
- Atmospheric properties (isoplanatic angle…)
- Observation of close binaries
- Can observe blue companions to red giants/supergiants
  - Sirius, O Ceti, etc…
- First results:

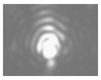
SAO 37735
V = 5.1, 6.3
separation = 0.34 arcsec



Speckle nulling on-sky trials

- Coma applied to the DM
- Dark area at the 2 x 10^{-3} level at ≈2λ/D
- Very long-lived speckles present
- Require NCP errors / long-lived speckle reduction
- Can move on to more complex phase distributions
- Potential wavefront sensing improvements:
  - non-common path error reduction
    - Phase diversity (S. Bikkannavar)
    - Electric field conjugation (A. Give'on)
  - predictive AO
  - spatially-filtered wavefront sensor





Benefits to NASA and JPL

Technological developments: new high-tech coronagraphs, optical subsystems optimization, wavefront management methods,… → Experience gain: high-contrast imaging and spectroscopy observing strategies → Preparatory work for NASA/JPL projects: Palm-3000, GPI, TMT-PFI, TPF and precursors ⇒ On-sky testbed => *Scientific return*

Publications

Crepp et al. 2007, Comparative Lyot Coronagraphy with Extreme Adaptive Optics Systems, ApJ 661, 1323
Give'on et al. 2007, Electric Field Conjugation - A Broadband Wavefront Correction Algorithm For High-contrast Imaging Systems, AAS Meeting #211, #135.20
Haguenauer et al. 2006, Astronomical near-neighbor detection with a four-quadrant phase mask (FQPM) coronagraph, Proc. SPIE 6265, 62651G
Mawet et al. 2005, Annular Groove Phase Mask Coronagraph, ApJ 633, 1191
Serabyn et al. 2007, Extreme Adaptive Optics Imaging with a Clear and Well-Corrected Off-Axis Telescope Subaperture, ApJ 658, 1386